COUNTS OF ATMOSPHERIC FREEZING NUCLEI AT PRETORIA, JANUARY 1956

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Summary

An account is given of freezing nucleus measurements made in aircraft at Pretoria, South Africa, during the month of January 1956. The measurements showed variations from day to day, which are discussed in relation to the prevailing weather situation. The possible connexion with particles from meteor showers is touched upon.

I. Introduction

The present paper describes daily measurements of the concentration of freezing nuclei in the atmosphere near Pretoria over the period January 3 to February 3, 1956. The apparatus used consisted of an airborne cloud chamber of 100 l. capacity and 10 l. illuminated volume, as described by Smith and Heffernan (1954). Samples of outside air were introduced by flushing with a strong air stream for 3 min. The chamber was then cooled at a rate of 4 °C/min and steam was introduced at the bottom to maintain a cloud of uniform and reproducible density. The illuminated cloud was examined visually and the number of ice crystals which appeared was recorded as a function of temperature. Complete glaciation of the cloud was observed at about −40 °C and the chamber was then warmed up to +10 °C ready for the next sample of outside air to be introduced.

The flights lasted from approximately 0900 to 1130 hr and were made early in the day to avoid turbulent mixing conditions as far as possible. The usual procedure was to take three air samples at 20,000 ft, two at 10,300 ft, and finally one at 5300 ft for analysis on the ground. (The heights given are heights above sea-level, Pretoria being at 4500 ft.) All sampling was done within a 30-mile radius of Pretoria. The 0 °C isotherm was generally at about 16,000 ft.

II. Experimental Results

In Figure 1 are plotted the temperatures at which the concentration of ice crystals reached 0·1, 1, and 10^3 per litre. These are the average values for the samples taken at a particular height.

The 0·1/l line indicates the temperature at which there was, on the average, always one ice crystal in the 10-l. illuminated volume. This ignores the isolated single crystals which sometimes appear from about −5 °C downwards. Since these isolated crystals may be of great meteorological importance, the total

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number appearing at and above −20 and −30 °C were also plotted, the readings taken at 20,000 ft each day being averaged. These two curves are very similar in general features to the 0·1/l and 1/l curves shown in Figure 1 (*a*), so they have not been included.

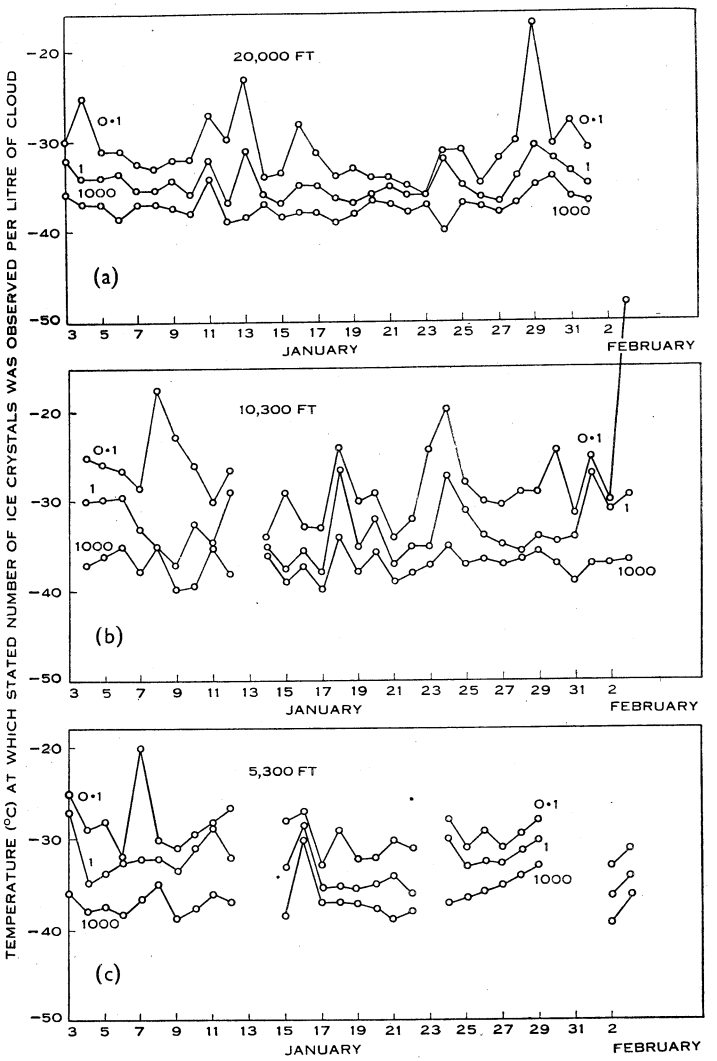

Fig. 1.—Daily plots of the temperature at which the concentration of atmospheric ice-forming nuclei reached the values indicated, at heights of 20,000, 10,300, and 5,300 ft above sea-level at Pretoria, over the period January 3 to February 3, 1956.

III. Meteorological Conditions

Since it is possible that the day-to-day fluctuations in the freezing nucleus content of the atmosphere may be considerably influenced by the previous history of the air mass in which measurements are made, the meteorological

situations during the period under consideration have been examined and the nature of the air mass at 20,000 ft is described below. It must be emphasized that, owing to the paucity of upper air soundings available, the air mass analysis can seldom be made with complete certainty.

January 3.—Dry hot continental air from west.

January 4–5.—Extremely dry superior air from south, with cool moist sea air below 10,000 ft.

January 6.—Deep moist unstable air of maritime origin. Widespread showers.

January 7–12.—Scattered light showers on 7th. The maritime air was displaced by tropical continental air following an anticyclonic trajectory from the south-east. Subsidence was indicated on the 8, 9, 10, 12th by drying of the air above 10,000 ft. Column became warm and moist on 11th.

January 13–16.—Deep warm moist air, uniform to 20,000 ft, probably maritime tropical air warmed over land. Widespread heavy rain on 13th, progressively less on 14th and 15th.

January 17–27.—Extremely dry subsided upper air from south-east. On 24th and 25th, isolated thunderclouds indicated increased penetration of surface air to high levels. There was a temporary increase of moisture content on the 26th.

January 28–29.—Maritime tropical air converged over Transvaal causing the air to be moist and unstable throughout. Widespread showers on both days.

January 30–February 2.—Reversion to subsidence conditions with very dry air at 20,000 ft.

February 3.—Similar conditions but there was sufficient convective activity in lower moist layers for widespread thunderstorms to build up.

IV. Discussion of Results

There was no marked scatter in the observations at a particular level on any one day, the temperatures for particular concentrations of ice crystals agreeing with the average value to about ± 2 °C. The only exception was on January 13, when the scatter among the six sets of readings at 20,000 ft for concentrations of ice crystals up to 10^2/l was about ± 6 °C.

The average temperature at which the ice crystal concentration reached 1/l was -34 °C at 20,000 ft, $-32 \cdot 5$ °C at 10,300 ft, and -33 °C at 5300 ft (500 ft above ground level at the aerodrome). Considering the day-to-day variations between individual readings it is doubtful whether the differences between these values are significant. Counts on 10 days scattered throughout December and February gave the same averages as those made during January. They are significantly lower than those made with similar apparatus at Sydney and at Arizona (Smith, Kassander, and Twomey 1956).

The meteorological conditions during January were unusual in that for long periods dry subsided air persisted above 10,000 ft and typical thunderstorm

conditions were virtually absent. These periods, namely, January 7–10, January 17–27, and January 30–February 2, coincided with low counts of freezing nuclei at 20,000 ft (possibly excepting January 30 and 31). Counts were, however, just as low on six days in February when the weather situation had changed completely, and humid tropical air gave widespread rain.

There were three occasions in January when there was deep moist unstable maritime air extending above 20,000 ft, namely January 6, 13–15, and 28–29. Rain fell at more than half of 49 stations within a 40-mile radius of Pretoria during these three periods. The heaviest and most widespread rains occurred on the 13th when the mean for all stations was 15 mm. At no other times during the period January 3 to February 3 was there anything but light isolated showers.

Of these dates, the 13th and 29th coincide with peaks in the ice crystal count. If we attempt to explain these peaks as being due to freezing nuclei carried up from the ground, it is difficult to understand :

(i) the absence of high counts on the 6th,

(ii) the non-persistence of high counts to the 14th and 15th,

(iii) the fact that the count at 20,000 ft on the 29th is higher than at 10,000 ft or near the ground. (Unfortunately the lower readings had to be omitted on the 13th owing to the lack of dry ice, so the same comparison cannot be made.)

If Bowen's meteoritic dust hypothesis is correct, then the absence of high ice crystal counts on or about January 22 points to non-uniform distribution of the dust particles. Some support for this is given by the observations of January 13 when three of the six air samples gave much higher ice crystal counts than the others. In these three cases the number of particles visible in the chamber before a cloud was formed was also much higher than usual.

V. Counts of Airborne Particles

It may be of interest to mention some auxiliary experiments in which daily counts were made of the number of particles collected upon spiders' threads exposed in the air stream at 20,000 ft for about $\frac{1}{2}$ hr. The average number of particles (virtually all non-hygroscopic) collected per $\frac{1}{2}$ in. length of thread, corrected to the same exposure time and air-speed, showed minor peaks on January 13 and February 1 and very large increases on January 21, 23, and 24.

VI. Conclusion

To summarize, one may therefore say that significant peaks were found in the counts of atmospheric freezing nuclei at 20,000 ft on January 13 and 29 and in the counts of non-hygroscopic particles on or about January 13, 23, and February 1.

Our results cannot be fully explained either by Bowen's meteoritic dust hypothesis or by suggesting that the counts are influenced by air mass changes. It is apparent that a full explanation can only be obtained by making further surveys of this kind in various parts of the globe.

VII. Acknowledgments

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